

## APPARATUS AND METHOD FOR FLEXING A WEB

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### FIELD

The present disclosure generally relates to web handling, and in particular to flexing a web to induce a permanent strain.

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### BACKGROUND

In web handling operations, curl is often present in multi-layered webs. Curl is defined as the tendency of a web to deviate from a generally flat or planar orientation when there are no external forces on the web. In multi-layered web systems, the curl can be controlled by carefully matching the strains of the webs being laminated together. In products that are direct-coated, such strain matching is much more complicated.

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Curl can be controlled in laminated multi-layer webs by carefully matching the strains of the incoming webs. Curl is more difficult to control in direct-coated products, especially where backings are placed under high tension and temperatures, resulting in large strains, while the coating cures at near zero strain. If the induced strain from tension, temperature and cure shrinkage is not matched between the layers, the final product will not lie flat.

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Flexing is a process that is used in the process of manufacturing abrasives. Flexing cracks the make-mineral-size coating in the abrasive article. This process makes the abrasive product flexible and reduces the propensity to curl. Sliding the (uncoated) backside of the abrasive over a small radius or pressing abrasive into a rubber roller using a small rotating bar are common flexing techniques. These techniques work very well in the common cases where the product tends to curl toward the abrasive side. These techniques can't be used with the abrasive coated on the contact side because of product damage and tool wear.

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Polymer backed abrasive products will have a propensity to curl toward the backing side when direct coated. Minimum line tensions and cure temperatures along with maximum cure shrinkage and backing modulus can help minimize curl problems, but

have limitations. If such optimization still results in unacceptable product curl, excess tensile strain will need to be removed from the backing. This could be done with thermal stress relief or by mechanically yielding the backing. Bending the backing around the outside of a small radius on an object will stress the backing to its yield point, causing permanent elongation in the backing.

### SUMMARY

An aspect of the invention of the present disclosure is directed to a system for flexing a web. The system includes a web handling apparatus having a first web handling assembly and a second web handling assembly. A gap is disposed between first and second web handling assemblies. The system also includes a web path a web passing through a web path. The web path includes a first portion along the first web handling assembly, a second portion in the gap, and a third portion along the second web handling assembly. The second portion includes a radiused segment having a radius. The system also includes means for controlling the radius of the radiused segment.

An aspect of the invention of the present disclosure is directed to a system for imparting a controlled strain, in a machine direction, to an indeterminate length web. The system includes a pair of co-rotating members with a gap therebetween and means for forming a radius on the web when the web is in the gap between the co-rotating members. In certain embodiments, the means for forming a radius is a pair of roller assemblies. In certain embodiments, the means for forming a radius is a pair of belt assemblies.

An aspect of the invention of the present disclosure is directed to a method of inducing a plastic deformation in a web. The method includes creating a web path including a first portion, a second portion, and a third portion, wherein the first portion passes along a first rotating member, the second portion includes a radiused section having an effective radius, and the third portion passes over a second rotating member. The first and second members are co-rotating members. A web is passed through the web path. A plastic strain is induced in the web when the web is passed through the radiused section.

## **BRIEF DESCRIPTION OF THE DRAWINGS**

The present disclosure will be further explained with reference to the appended figures wherein like structures are referred to by like numerals throughout the several views, and wherein:

5           **FIG. 1** is a perspective view of an example embodiment of a system according to the present disclosure.

**FIG. 1A** is a close-up view of a section of the system of **FIG. 1**.

**FIG. 2** is a perspective view of another example embodiment of a system according to the present disclosure.

10          **FIG. 2A** is a close-up view of a section of the system of **FIG. 2**.

**FIG. 3** is a plan view of example embodiment of an article made on a system for flexing a web according to the present disclosure.

**FIG. 4** is a perspective view of another example embodiment of an article made on a system for flexing a web according to the present disclosure.

15          **FIG. 5** is a perspective view of another example embodiment of an article made on a system for flexing a web according to the present disclosure.

**FIG. 6** is an illustration of a stress-strain curve.

## **DETAILED DESCRIPTION**

20           In the following detailed description, reference is made to the accompanying drawing that forms a part hereof, and in which is shown by way of illustration exemplary embodiments in which the disclosure may be practiced. It is to be understood that other embodiments may be utilized, and structural or logical changes may be made without departing from the scope of the present disclosure. The following detailed description, 25 therefore, is not to be taken in a limiting sense, and the scope of the present disclosure is defined by the appended claims.

          The present disclosure is directed to a system and method for inducing a strain in a web, which can be used to remove curl from a web. Alternatively, the system can also be used to impart a predetermined curl to the web. The system and method can be used with 30 webs having a single or multiple layers. The system includes first and second rotating assemblies having a gap therebetween. First and second assemblies co-rotate, which means they have the same direction of rotation; or in the case of opposed belt assemblies,

the opposed belt assemblies have opposite directions of linear travel. As a result of two members being co-rotating, if portions of their respective rotating surfaces are placed in close proximity, the relative linear motion of the surfaces will be in opposite directions. For example, both first and second assemblies could rotate together in a clockwise direction, and the surfaces in close proximity would have opposite directions of travel.

Typically, the first and second rotating assemblies are of the same type; for example, both are roller assemblies or belt assemblies. Upon reading this disclosure, one having the knowledge and skill of one of ordinary skill in the art will appreciate that other rotating assemblies could be used in place of roller or belt assemblies.

The rollers are placed in proximity so that a desired gap is created therebetween. A web path is created that passes over a portion of the first assembly, through the gap, and then over the second assembly. A web passing through the web path includes a radiused portion in the gap. The radiused portion of the web is controlled to a predetermined radius. The predetermined radius is selected to impart a set strain on the web. The predetermined radius can vary with time, as will be described hereinafter.

Referring to FIG. 1, an exemplary embodiment of a system **100** for flexing a web to induce a permanent strain in the web is shown. The system **100** includes a first rotating assembly **110** and a second rotating assembly **120**. In the example embodiment illustrated, first and second rotating assemblies **110**, **120** are roller assemblies **111**, **121**. Each roller assembly **111**, **121** includes a roller **112**, **122** and means for supporting the roller (such as a frame connected to a roller bearing (not shown)). Each roller is driven and controlled by a control system **150**, as will be described further below. A gap **G** is created when the rollers are placed in close proximity. Generally, the gap **G** is defined by the location where the first and second rollers are nearest one another.

Roller assemblies **111**, **121** co-rotate, which means they rotate in the same direction **A**, **A'** relative to a fixed axis of each roller. A web path **W** is formed through the system **100**. The web path **W** includes a first portion **W1** passing over the first roller **112**, a second portion **W2** passing into or through the gap **G**, and a third portion **W3** passing over the second roller **122**. The second portion **W2** of the web path **W** is controlled to form a radiused portion **125**. By passing a web **130** through the second portion **W2**, the web can be flexed and a strain induced in the web in the machine direction, that is, the direction along the direction in which the web travels. The amount of strain induced in the

web is a function of the bend radius **R** of the radiused portion **125**. By flexing a web above its plastic deformation point, which is typically around 2% for most materials, a permanent strain can be imparted to the flexed portion of the web.

To flex the web, the web is passed over the two co-rotating members and through the gap. Typically, the web is held against the co-rotating members by holding means such as, for example, an electrostatic pinning wire (**140** as is illustrated in FIG. **1a**), air pressure or vacuum, adhesives, or engagement members, for example, hook and loop fasteners. Using the holding means allows control of where the web leaves and enters points **T**, **T'** of the respective co-rotating members. It also counteracts the tendency of the web to move out of the gap, such tendency being caused by the rollers rotating in the same direction. One example of a holding means that can be used to hold the web against the co-rotating members is a charging bar with a trade designation TETRIS, available from SIMCO Industrial Static Control, Hatfield, Pennsylvania.

Generally, the web travels around the first co-rotating member and is peeled off at point **T** in the vicinity of the gap. The web is then bent back on itself in a small radius **R** (at the radiused portion **125**) and reattached at a point **T'** on the second co-rotating member. In the example embodiment described, the location of the radiused portion **125** is fixed with a closed loop control system **150** sensing the radiused portion's **125** location and controlling the relative velocity of the two rotating members.

The size of the radius **R** of the web can be varied by controlling the size of the gap and the distance that the web extends into or through the gap. In one exemplary embodiment, the web radius **R** can be controlled by using a sensor **160** to sense the position of the radiused portion **125** in the gap **G** (for a fixed gap dimension), since the curvature (radius) of the radiused portion **125** will depend on the distance that the radiused portion **125** extends into the gap, the material thickness, and the tangent points **T**, **T'** at which the web loses contact with the rollers. Once the relationship of the web curvature of the radiused portion **125** is determined, a sensor **160** is used to measure the position of the radiused portion **125** of the web while in the gap **G**. The sensor **160** can then send a signal to the means for controlling the rollers, such as a programmable controller, which can then adjust operation of the system to position the radiused portion **125** to obtain the desired curvature. For example, if the sensor detects that the radiused portion **125** has moved too far into the gap **G**, it can adjust the relative speed of the rollers to reposition properly the

radiused portion **125** in the gap **G**. One way would be to increase the speed of the second roller relative to the first roller, which would tend to move the radiused portion **125** towards the gap **G**. Alternatively, the speed of the first roller could be decreased relative to the speed of the second roller until the radiused portion **125** is repositioned as desired.

5 Upon reading this disclosure, other means for properly positioning the radiused portion of the web in the gap **G** will become apparent to an artisan having ordinary knowledge and skill in the art, such as using a pacing roll and a follower roll.

The example embodiment described above can be operated to remove/add curl to/from a web. The system can be integrated into a web handling process machine, such as a printing press, or it can be used as a separate operation to remove/add curl from/to a product. To control the amount of curl, a web is positioned along the web path described above. The radiused portion is then controlled by sensing the position of the radiused portion when the web is traveling, and correction is made by controlling the relative speed of the rollers to adjust the position as desired. Typically, it is preferred that the radiused portion extend through the narrowest point in the gap, as is illustrated in **FIGS. 1** and **2**.

10 However, it may be desirable for the radiused portion to extend into the gap to a lesser extent and not through the point at which the rotating members are nearest to one another, as shown by web path **V**. When the rotating assemblies are rollers, the size of the radiused portion is sensitive to the amount that the radiused portion extends towards or into the gap, as well as the gap size. This sensitivity can be made to be only a function of the gap size, as will be discussed below.

Referring to **FIG. 2**, another exemplary embodiment of a system **200** for flexing a web to induce a permanent strain in the web is shown. The system **200** includes a first rotating assembly **210** and a second rotating assembly **220**. In the example embodiment illustrated, first and second rotating assemblies **210**, **220** are belt assemblies **211**, **221**.

25 Each belt assembly **211**, **221** includes a driven belt **212**, **222** and means for supporting the belt (such as a frame connected to rollers **214**, **215** not shown). Each belt **212**, **222** is driven and controlled by a control system **250**, as will be described further below.

Belt assemblies **212**, **222** co-rotate, which means they rotate in the same direction **B**, **B'** relative to a fixed axis **F2**, **F2'**. A web path **W'** is formed through the system **200**. The web path **W'** includes a first portion **W1'** passing over the first belt **212**, a second portion **W2'** passing through the gap **G'**, and a third portion **W3'** passing over the second

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belt **222**. The second portion **W2'** of the web path **W'** is controlled to form a radiused portion **225**. By passing a web **230** through the radiused portion **W2'**, the web **230** can be flexed and a strain induced in the web in the machine direction, that is, the direction along the direction in which the web travels.

5           As long as the radiused portion **225** of the web is located between the respective ends of the first and second belts forming the gap **G**, the curvature of the radiused portion **225** is only a function of the size of the gap **G**, since the tangent **T2** at which the web **230** leaves the first belt **212** and rejoins the second belt **222** is constant between the ends of the first and second belts **212**, **222**, as long as the belts are substantially parallel along their  
10       respective flat portions. Thus, once the radiused portion **225** is formed while the system is operating, the system can be run without a sensor for detecting the position of the radiused portion **225** of the web **230** in the gap **G**. However, since there is typically some drift of the position of the radiused portion **225** of the web **230** in the gap **G**, it is typical to have a sensor detect the position of the radiused portion to keep the radiused portion **225**  
15       positioned within the gap **G**. Such a sensor would require less sensitivity than the sensor required for the example embodiment using rollers.

          The systems **100**, **200** described above can be used as an independent system and can also be integrated into a machine for processing a web. Such integration would allow curl to be removed from or added to a web in addition to having other modifications being  
20       done to the web, such as coating, converting, or printing, or combinations thereof.

          An advantage of the invention of the present disclosure is that a web can be flexed without any contact of the surface of the web that is not in contact with the web handling assemblies. For example, many abrasive products are made by direct coating. In direct coating, backings are placed under high tension and temperature, which results in a large  
25       induced strain. The coating on the backing usually has negligible strain, which can approach zero strain. If the induced strain in the backing is not removed, the resulting coated abrasive product will have curl.

          The curl can be removed or reduced by passing the direct-coated product in web form through the systems described above. A web path can be created such that the coated  
30       side of the web does not contact the surface of any web handling assembly. The web is then passed through a web path having a radiused portion. Since the coated side of the web does not contact rollers or belts, there is a reduction in the chance that the coated side

of the web will be damaged by contact. Also, since the coated side does not contact any surfaces in the system, the amount of wear is reduced or eliminated.

The size (or curvature) of the radiused portion controls the amount of strain that is induced in the web. The radiused portion is sized so that the web material is strained to just beyond its elastic point, thereby insuring the strain induced is a permanent strain. The particular size of the radius will depend on many factors, such as the material properties and thickness of the material (or multi-layer web). Determining the radius to which the web must be flexed to create permanent strain is within the skill and knowledge of one having ordinary skill in the art. The yield stress, that is the point where the web undergoes plastic deformation, can be determined by routine testing, such as that done using a mechanical tester, for example Model 4505, available from INSTRON Co., of Canton, Massachusetts.

An advantage of the invention of the present disclosure is that it can be used to impart curl to a web that varies as a function of position within the web in the machine direction. The systems described herein can be used in a process for manufacturing a web with variable curl as a function of down web position. This is accomplished by controlling the flex loop diameter (size of the radiused portion) as a function of machine direction position, that is varying the size as a function of time. This type of processing would allow products such as self-curling markers, described hereinafter, to be made on high-speed web lines. For example, the systems described above could be integrated on a printing press to make such self-curling markers.

Referring to **FIG. 3**, an example embodiment of an article **300** for marking and recording is illustrated. The article includes a sheet **310** of material, which has removable curled markers **320** attached to the sheet **310**, as well as having the marker information **330** printed/recorded on the sheet **310**. The sheet **310** design provides organization, permanent record keeping, and a carrier substrate for curled markers **320** that can be removed and placed on items to be marked, for example, wires or cables. Each individual marker **321** has a unique identifier, for example, symbols such as letters and numbers and combinations thereof. When a marker **321** is attached to the item to be marked, a descriptor of the item so marked can be recorded on the sheet **310** next to its appropriate identifier **322**. The curled markers **321** can also include an adhesive for securing each marker to its respective marked item.



The articles described above can be made using the exemplary systems described above. Typically, the article includes a sheet having a flat (planar) portion and a curled portion. One method of making such an article would include custom preprinting of a web with a repeating pattern. The preprinted web would include removable markers with identification symbols and a place to record a description of any item to which the marker is attached. The sheet could include perforations so that each individual marker could be easily removed or detached from the sheet. Referring to **FIGS. 4** and **5**, typically, each marker **421, 521** would have a generally planar end **423, 523**, including the identification symbols, and an outer section **424, 524** of the label having a tight curl, typically forming a tube. The tube would preferably consist of at least one complete wrap of the curled web. The marker could then be placed around a wire by grasping or securing the planar end, placing the curl against the wire, then pulling to uncoil the tube until only the end is wrapped around the item to be marked. Following the process described, after releasing the marker, the marker would self-wind around the wire.

The article for marking described above could be formed on a web by creating alternating tight curl/no curl sections on the web. This could be done on a web line such as a printing press. Alternatively, a separate apparatus could be used on a pre-printed web to add alternating sections of curl/no curled sections to the web. After printing and straining the web to create curled portions, the web could be converted into individual articles for marking.

If the flexing systems described are used on a printing press, the perforating process could be setup in a customary manner known to those having ordinary skill in the art. A process for flexing a web, as described herein, could be setup upstream or downstream of the perforating process. This process would consist of two closely spaced rotating assemblies, such as the example embodiments of belts or rollers disclosed herein. The rotating assemblies would have a means of holding the web, such as electrostatic pinning, vacuum, mechanical fasteners or adhesive. One of several means could be used to control the radius of the radiused portion. First, one roll could be held at constant speed, and the speed of the other roller could be adjusted. This would allow the loop to be drawn toward the center of the two rollers in order to form a tight loop and thus a curled section of web. The speed of the roller could then be changed to make a large diameter loop and therefore a flat web. The same small loop/large loop cycles could be

accomplished at constant speed by holding the loop position constant and adjusting roller gap.

5       The present disclosure has now been described with reference to several  
embodiments thereof. The foregoing detailed description and examples have been given  
for clarity of understanding only. No unnecessary limitations are to be understood  
therefrom. It will be apparent to those skilled in the art that many changes can be made in  
the embodiments described without departing from the scope of the disclosure. Thus, the  
scope of the present disclosure should not be limited to the exact details and structures  
described herein, but rather by the structures described by the language of the claims, and  
10   the equivalents of those structures.